Course Companion

International Baccalaureate · IB Diploma · Environmental Systems and Societies · SL

Every topic handout in one volume

exercises.lol

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Foundation

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Scope and prerequisites

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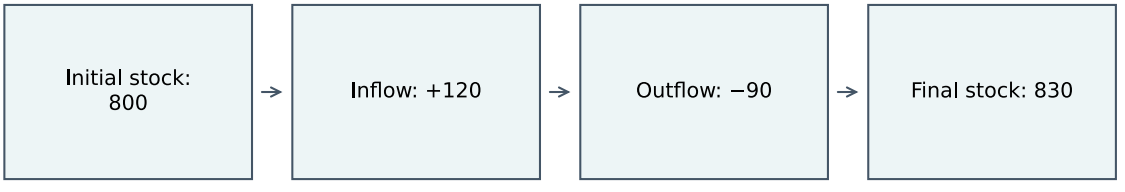
Environmental systems, feedback and perspectives

■ What would explain this observation?

- A lake can respond to the same nutrient input differently depending on its current state. Environmental outcomes depend on **stocks**, **flows** and feedback.

■ Build the model

- A system model has a boundary, stores and flows.
- Negative feedback counteracts change; positive feedback amplifies it.
- An environmental perspective shapes what people value and which management outcomes they prioritize.
- stock : An amount held within a system.
- flow : Transfer of an amount per unit time.



$$\textit{Final stock} = \textit{initial stock} + \textit{inflows} - \textit{outflows} = 800 + 120 - 90 = 830$$

Choose evidence that can test it

- Separate physical evidence from value judgements.
- A stock is an amount at a time; a flow is an amount per time.
- Sustainability decisions require ecological, social and economic evidence and a stated scale.

In the lab: Draw the system boundary before calculating a budget. Identify inflows, outflows and possible unmeasured terms. Compare stakeholder claims using the same evidence, then explain where values lead to different choices.

Work from known quantities

- Known: a reservoir begins with 800 units, receives 120 and loses 90 during a week.
- Change in storage = inflow-outflow = 120-90 = 30.
- Final storage = 800+30 = 830 units.
- The model assumes no omitted flow.

Your turn: A stock starts at 600, receives 80 and loses 110. Find final stock.

Check the conclusion and its limits

- A balance that closes mathematically can still omit a real process if terms were estimated to fit.
- Positive feedback does not mean a socially desirable result.

Not true: Positive feedback always produces a socially beneficial outcome. "Positive" in positive feedback means the change is AMPLIFIED, not that the outcome is good. Melting permafrost releasing methane is positive feedback with harmful consequences; desirability is a separate judgement.

Key:

- A system model has a boundary, stores and flows.
- Separate physical evidence from value judgements.
- Watch for: A balance that closes mathematically can still omit a real process if terms were estimated to fit.

Write from a final stock of 475

- A store starts at 450 units, receives 60 and loses 35.
- Find the final stock. Positive feedback means a change is amplified, not that the outcome is good.

Ecology

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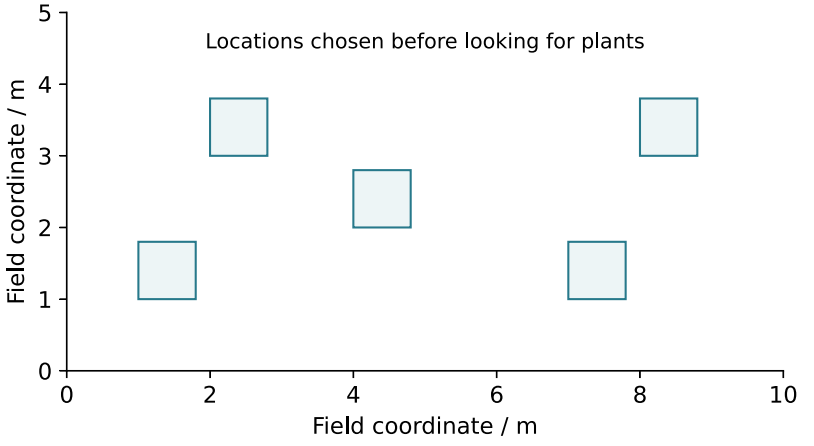
Sampling populations without choosing the answer

What would explain this observation?

- A field edge looks richer in plants than its centre. Choosing only the richest patches would build the desired result into the sampling method.

Build the model

- A **population** consists of organisms of one species in a defined area.
- Random **quadrats** estimate density without deliberately selecting patches.
- A transect investigates change along an environmental gradient.
- quadrat : A defined area used for sampling.
- population: Organisms of one species in a defined area.



Quadrat positions chosen before looking at the plants avoid sampling bias

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Choose evidence that can test it

- Estimate total abundance by multiplying mean density by area, with consistent units.
- This assumes sampled areas represent the habitat.
- Patchiness and too few samples widen uncertainty.

In the lab: Choose coordinates with random numbers before visiting the patches. Record quadrat area and counting rules. For a transect, use fixed distances and measure a relevant abiotic variable. Do not damage habitats or sample unsafe locations.

Work from known quantities

- Known: five 0.25 square metre quadrats contain 3, 4, 6, 5 and 2 plants.
- Mean count = 20/5 = 4.
- Density = 4/0.25 = 16 plants per square metre.
- Estimated abundance in 100 square metres = 16 × 100 = 1,600 plants.

Your turn: Mean count is 6 in a 0.5 square metre quadrat. Find density per square metre.

Check the conclusion and its limits

- Quadrats suit organisms that do not move quickly.
- A food chain arrow shows the direction of energy transfer, not the direction a predator travels.

Not true: Sampling only the most crowded patches gives an unbiased population estimate. Choosing the most crowded patches overestimates density, because the samples are not representative of the whole area. Unbiased estimation needs random or systematic sampling decided before looking at the plants.

Key:

- A population consists of organisms of one species in a defined area.
- Estimate total abundance by multiplying mean density by area, with consistent units.
- Watch for: quadrats suit organisms that do not move quickly.

Write from a density of 20 plants per square metre

- The mean count is 5 plants in a 0.25 square metre quadrat.
- Find the density per square metre. Sampling only crowded patches overestimates density.

Biodiversity and conservation

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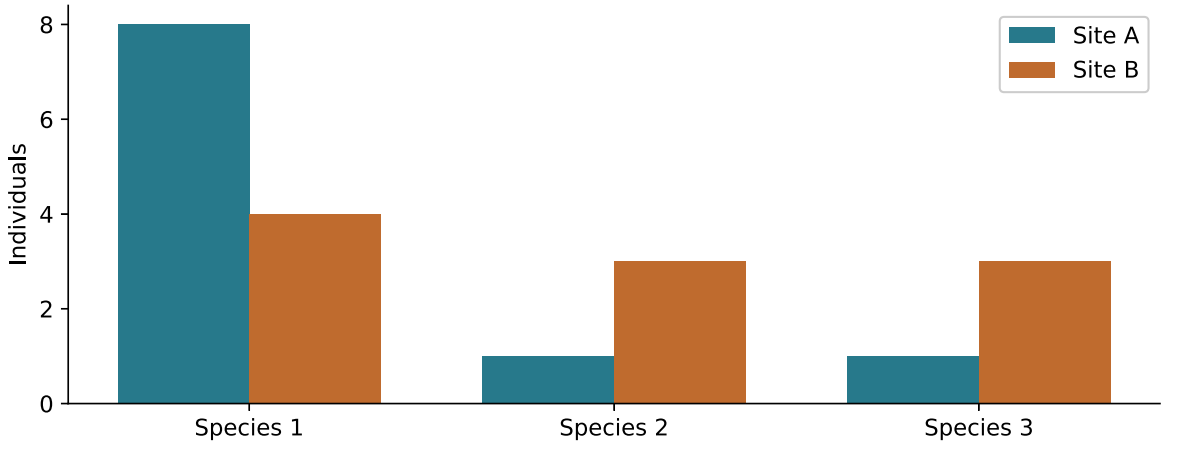
Biodiversity, conservation and sampling evidence

What would explain this observation?

- A site with many individuals can still be dominated by one species. Abundance, richness and **evenness** describe different features of biodiversity.

Build the model

- **Species richness** counts species.
- Evenness concerns relative abundance.
- Conservation can protect habitats, populations or genetic diversity; a management judgement must state the conservation goal.
- species richness: The number of species recorded.
- evenness: How evenly individuals are distributed among species.



Same richness, different evenness: site B is more even

Choose evidence that can test it

- Compare surveys with similar area, effort, season and identification rules.
- A diversity index is meaningful only with its formula and conventions specified.
- Habitat fragmentation can affect movement and gene flow even when total area changes little.

In the lab: Use non-destructive field sampling approved by the school. Identify organisms with a suitable key and record uncertain identifications rather than inventing species. Combine ecological evidence with stakeholder perspectives on land use.

Work from known quantities

- Known: site A has counts 8, 1 and 1; site B has 4, 3 and 3.
- Both have richness 3 and total abundance 10.
- The most abundant species occupies 80% in A and 40% in B.
- B is more even under these counts.

Your turn: A survey records 6, 5, 3 and 2 individuals in four species. Find species richness.

Check the conclusion and its limits

- An index cannot by itself explain the cause of a difference.
- A newly recorded species may reflect improved observation rather than a recent ecological arrival.

Not true: A larger total number of individuals always means greater species richness. Richness counts how many species are present, not how many individuals. Ten thousand individuals of one species give richness 1, while ten species with one individual each give richness 10.

Key:

- Species richness counts species.
- Compare surveys with similar area, effort, season and identification rules.
- Watch for: an index cannot by itself explain the cause of a difference.

Write from a richness of 5

- A survey records 7, 2, 2, 2 and 1 individuals across five species.
- State the species richness. A larger total of individuals is not greater richness.

Water

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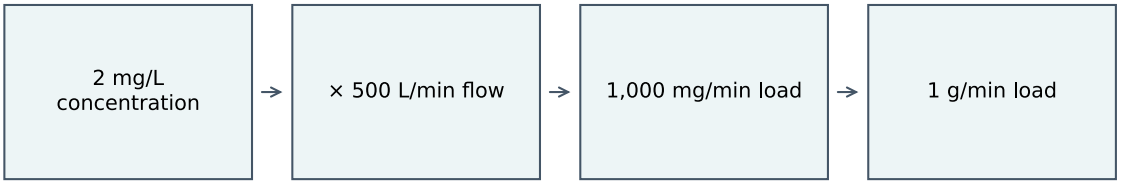
Water, pollution and management trade-offs

■ What would explain this observation?

- A downstream sample has less dissolved oxygen after a nutrient input. The explanation must connect biological processes with the water-system evidence.

■ Build the model

- **Eutrophication** can begin with nutrient enrichment, followed by greater producer growth and increased decomposition after organisms die.
- Decomposer respiration can lower dissolved oxygen.
- Water availability depends on quantity, quality and access.
- eutrophication: Nutrient enrichment with ecological consequences.
- **pollutant load** : Mass of pollutant transferred per time.



$$Load = concentration \times flow = 2\ mg/L \times 500\ L/min = 1{,}000\ mg/min = 1\ g/min$$

Choose evidence that can test it

- Distinguish concentration from total pollutant load.
- Dilution can reduce concentration without removing the pollutant mass.
- A management plan should consider upstream causes, users and effects on other parts of the catchment.

In the lab: Collect approved water-quality observations at matched sites and times. Use calibrated instruments and consistent sampling depth. Avoid contact with contaminated water and do not infer potability from clarity.

Work from known quantities

- Known: concentration is 2 mg per litre and flow is 500 litres per minute.
- Load = concentration × flow = 2×500 = 1,000 mg per minute = 1 g per minute.
- A lower concentration during high flow can still produce a high total load.

Your turn: Concentration is 3 mg/L and flow 200 L/min. Find load in mg/min.

Check the conclusion and its limits

- Clear water is not necessarily safe water.
- Nutrient enrichment does not directly use up oxygen; the pathway includes biological activity and decomposition.

Not true: Clear water is always safe to drink. Clarity shows only that little is suspended. Dissolved metals, pathogens and many chemicals are invisible; safety requires testing against standards, not looking at the water.

Key:

- Eutrophication can begin with nutrient enrichment, followed by greater producer growth and increased decomposition after organisms die.
- Distinguish concentration from total pollutant load.
- Watch for: clear water is not necessarily safe water.

Write from a load of 400 mg per minute

- Concentration is 5 mg per litre and flow is 80 litres per minute.
- Find the load. Clear water is not evidence that the water is safe to drink.

Land

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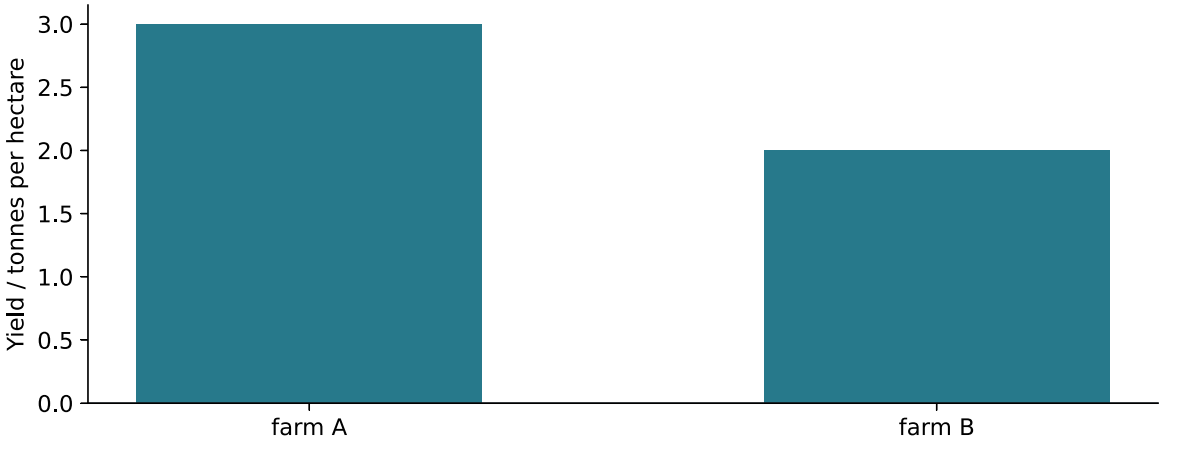
Land, food and resource decisions

What would explain this observation?

- A farm can increase yield while increasing soil loss or water demand. Food-system evaluation requires more than tonnes harvested.

Build the model

- Soil supports nutrient cycling, water storage and organisms.
- **Erosion** removes soil; nutrient depletion changes fertility.
- **Resource** use involves extraction, production, distribution and waste.
- erosion: Removal and transport of soil or rock.
- resource: A material or service used to meet needs.



Compare yield per hectare, not total harvest: 18 t ÷ 6 ha = 3 t/ha against 20 t ÷ 10 ha = 2 t/ha

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Choose evidence that can test it

- Distinguish total yield from yield per area and energy input.
- Sustainable management must consider regeneration rates and impacts beyond the farm boundary.
- Different stakeholders may rank food security, biodiversity and income differently.

In the lab: Compare management options using a stated functional unit and the same timescale. Use approved secondary datasets or non-destructive soil observations. Explain trade-offs instead of claiming a method has no disadvantages.

Work from known quantities

- Known: farm A harvests 18 tonnes from 6 hectares.
- Yield per area = 18/6 = 3 tonnes per hectare.
- Farm B harvests 20 tonnes from 10 hectares, so its yield is 2 tonnes per hectare despite a larger total harvest.

Your turn: A farm harvests 28 tonnes from 7 hectares. Find yield per hectare.

Check the conclusion and its limits

- A high yield is not proof of long-term soil health.
- Renewable resources can be depleted when use exceeds regeneration.

Not true: A renewable resource cannot be depleted. Renewable means the resource can regenerate, not that it regenerates faster than every possible rate of use. Fish stocks and soils are renewable yet have been depleted when harvest exceeded renewal.

Key:

- Soil supports nutrient cycling, water storage and organisms.
- Distinguish total yield from yield per area and energy input.
- Watch for: A high yield is not proof of long-term soil health.

Write from a yield of 5 tonnes per hectare

- A farm harvests 40 tonnes from 8 hectares.
- Find the yield per hectare. A renewable resource can still be depleted.

Atmosphere and climate change

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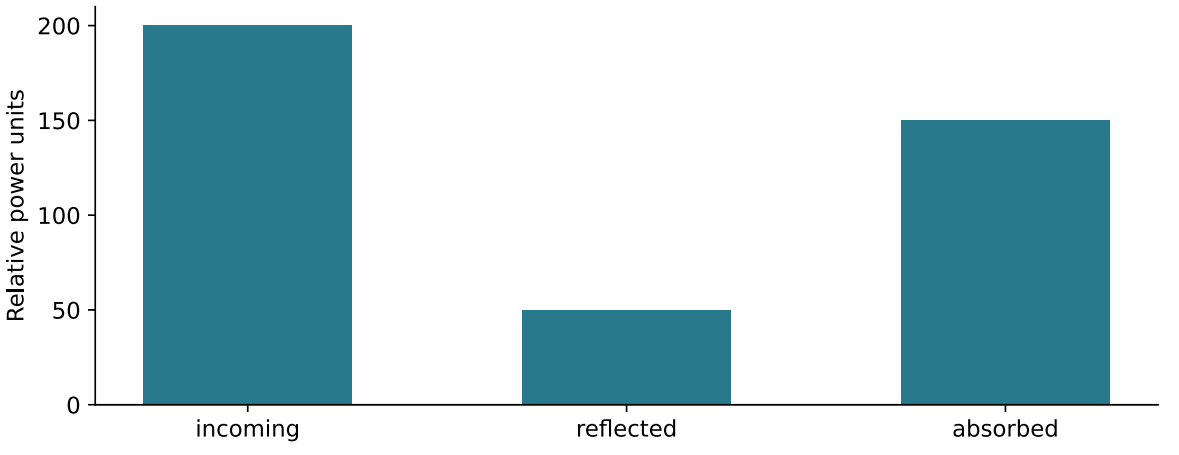
Climate evidence, energy budgets and policy

■ What would explain this observation?

- One cold day does not disprove a warming climate. Weather describes short-term conditions; climate describes distributions over longer times and regions.

■ Build the model

- The Earth energy balance includes incoming solar radiation, reflection, absorption and outgoing infrared radiation.
- Greenhouse gases absorb and emit infrared radiation.
- Feedback can alter the response to an initial forcing.
- **mitigation** : Actions addressing causes of environmental change.
- **adaptation** : Actions reducing harm from environmental impacts.



Absorbed = incoming − reflected: 200 − 50 = 150 units

Choose evidence that can test it

- Distinguish mitigation, which addresses drivers, from adaptation, which reduces harm from impacts.
- A policy assessment needs evidence about effectiveness, cost, equity and uncertainty; one criterion is not the entire decision.

In the lab: Compare multi-year data using consistent baselines. State the region, timescale and uncertainty. At HL, connect a management decision to law, economics and ethics rather than treating these lenses as extra definitions only.

Work from known quantities

- Known: a surface receives 200 power units and reflects 50.
- Absorbed input = incoming-reflected = 200-50 = 150.
- Reflected fraction = 50/200 = 0.25 = 25%.
- A change in reflectivity alters the absorbed budget under this model.

Your turn: Incoming energy is 240 units and reflected energy 72. Find reflected percentage.

Check the conclusion and its limits

- The greenhouse effect is not the same process as ozone depletion.
- A carbon footprint estimate depends on its system boundary.

Not true: One local weather observation establishes a global climate trend. Weather is a short-term local state; climate is the long-term statistical pattern. One cold day in one city cannot confirm or refute a global trend built from decades of worldwide records.

Key:

- The Earth energy balance includes incoming solar radiation, reflection, absorption and outgoing infrared radiation.
- Distinguish mitigation, which addresses drivers, from adaptation, which reduces harm from impacts.
- Watch for: the greenhouse effect is not the same process as ozone depletion.

Write from 20 percent reflected

- A surface receives 500 energy units and reflects 100.
- Find the reflected percentage and the absorbed input. One local weather observation does not establish a climate trend.

Natural resources

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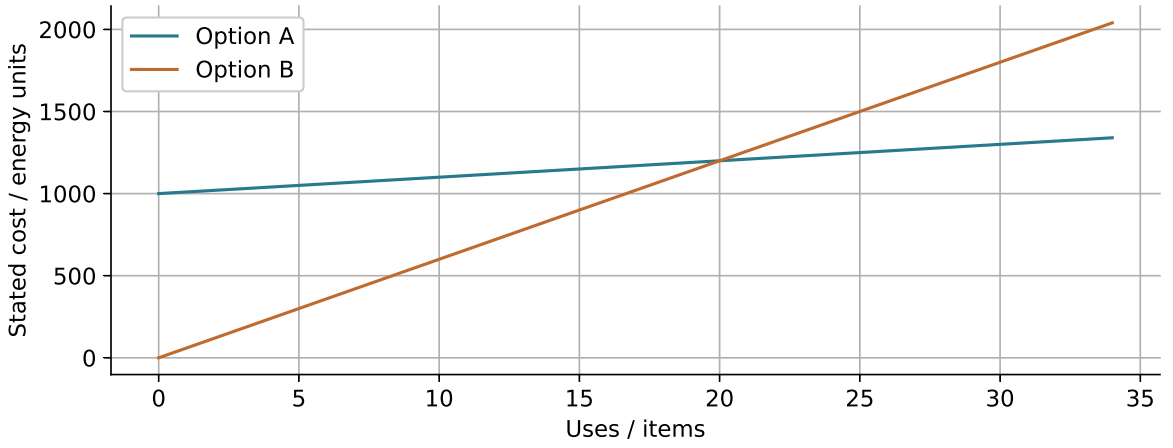
Natural resources: soils, yields and trade-offs

■ What would explain this observation?

- Two farms report the same total harvest. The one using half the land is not automatically more sustainable: **natural resources** regenerate at their own rates.

■ Build the model

- Soil is a resource: its removal and transport, by water, wind or gravity, is a loss measured beyond one season.
- Sustainable management weighs total **yield** per area and per energy input against regeneration rates and impacts beyond the farm boundary.
- Different stakeholders may rank food security, biodiversity and income differently.
- yield: The useful output of a managed system, per stated basis.
- natural resources: Materials and energy sources supplied by ecosystems and used by people.



The reusable item wins after 20 uses: 1,000 + 10n = 60n

■ Choose evidence that can test it

- Compare management options using a stated **functional unit** and the same timescale.
- Use approved secondary datasets or non-destructive soil observations.
- Explain trade-offs: no method is without disadvantages.

In the lab: State the functional unit (per hectare, per tonne, per gigajoule) before comparing, and keep the timescale identical.

■ Work from known quantities

- Known: farm A harvests 12 t from 4 ha (3 t per ha) using 40 GJ; farm B harvests 12 t from 2 ha (6 t per ha) using 25 GJ.

Your turn: A third farm matches B's per-hectare yield but feeds its soil nothing back. Which basis of comparison is still missing?

■ Check the conclusion and its limits

- A comparison is only as good as its stated functional unit and timescale.
- Stakeholder priorities differ: a food-security ministry and a conservation body can rank the same data differently, both correctly.

Not true: The higher-yielding farm is automatically the more sustainable one: regeneration and beyond-boundary impacts decide otherwise.

Key:

- State the functional unit and the timescale before comparing.
- Total yield, yield per area and per energy input are different claims.
- Watch for: impacts beyond the farm boundary and differing stakeholder priorities.

Write from a functional unit

- Two farms are compared per farm and per 1 000 kg of grain.
- Per farm compares whole farms; per 1 000 kg of grain compares equal food output. Choose a functional unit that matches the stated question, with equivalent function and the same timescale.

Write from three yield claims

- A farm yields 12 t on 2 ha with 40 GJ of energy input.
- Total 12 t; per area $12 \div 2 = 6$ t per ha; per energy $12 \div 40 = 0.3$ t per GJ – three different claims from one farm.

Write from a boundary stakeholder

- Irrigation water leaves the farm boundary and reaches downstream users.
- Name them in the trade-off: an impact beyond the boundary is still an impact of the system.

Human populations and urban systems

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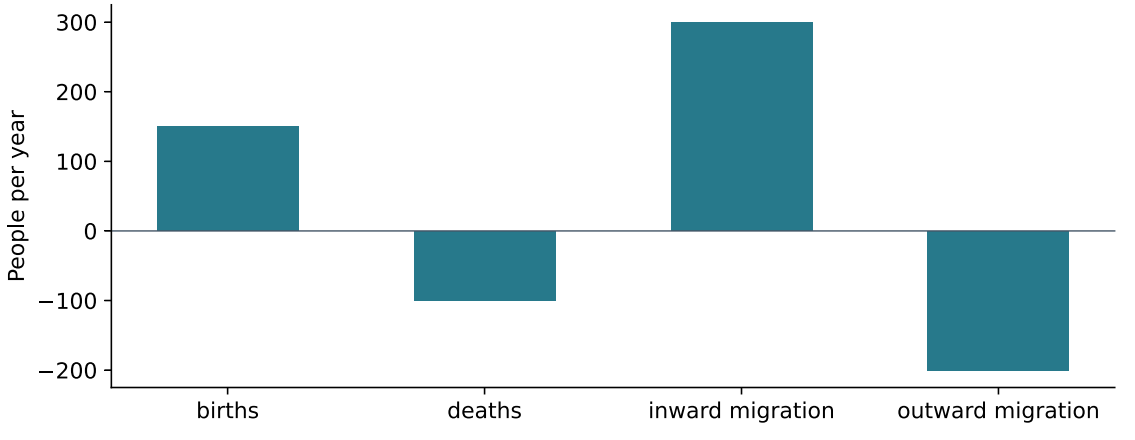
Population, urban systems and indicators

What would explain this observation?

- A city can grow because people move into it even when births equal deaths. Population change has several flows.

Build the model

- Population change depends on births, deaths, **immigration** and emigration.
- Urban systems exchange energy, materials and waste with a wider region.
- A sustainability **indicator** measures a specified feature rather than total wellbeing.
- immigration: Movement into a population.
- indicator: A measure of a specified condition.



Change = births − deaths + immigration − emigration = +150 people, 1.5% of 10,000

Choose evidence that can test it

- Compare rates with a common denominator and interval.
- An average can hide unequal access to services.
- At HL, evaluate how economic incentives, legal responsibilities and ethical priorities change an urban management proposal.

In the lab: Use published demographic and city-service data with dates and definitions. Protect privacy when collecting local opinions. Compare the same geographical boundary rather than mixing an urban core with a whole metropolitan region.

Work from known quantities

- Known: a city has 10,000 people; births 150, deaths 100, immigration 300 and emigration 200 in one year.
- Change = 150-100+300-200 = 150.
- Growth percentage = 150/10,000×100 = 1.5%.

Your turn: A population of 2,000 grows by 40 in a year. Find percentage growth.

Check the conclusion and its limits

- A projected population is conditional on assumptions.
- Urban growth does not automatically mean improved health, income or environmental quality for every resident.

Not true: Population growth depends only on births and deaths. Population change = births - deaths + immigration - emigration. A country with more deaths than births can still grow through net immigration, so births and deaths alone do not decide it.

Key:

- Population change depends on births, deaths, immigration and emigration.
- Compare rates with a common denominator and interval.
- Watch for: A projected population is conditional on assumptions.

Write from 1 percent growth

- A population of 5,000 has 90 births, 40 deaths, 30 immigrants and 30 emigrants in one year.
- Find the percentage growth. Population change is not births and deaths alone.

Experimental programme

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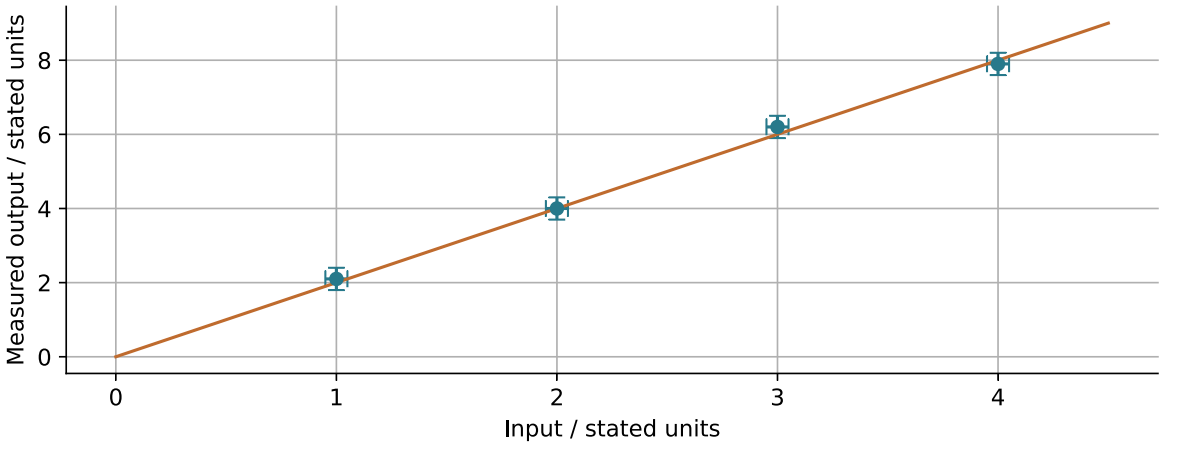
Uncertainty , gradients and model testing

What would explain this observation?

- A line passing near every data point is useful, but its gradient can still be uncertain. A graph is evidence for a model within the measurement range.

Build the model

- Random variation makes repeated readings differ.
- **Systematic error** shifts results consistently.
- Absolute **uncertainty** has the measured unit; relative or percentage uncertainty compares uncertainty with the measured value.
- uncertainty: A quantified limitation on a measured result.
- systematic error: A consistent measurement bias.



Every point lies within its uncertainty of the line of best fit

Choose evidence that can test it

- For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation.
- For a difference, add absolute uncertainties.
- A nonzero intercept can reveal an offset or an incomplete model.

In the lab: Show units on axes and choose a sensible scale. Plot uncertainty bars where justified, draw a best-fit line rather than joining every point, and estimate steepest and shallowest plausible gradients when the course method calls for them.

Work from known quantities

- Known: length = 50.0 mm with uncertainty 1.0 mm.
- Percentage uncertainty = absolute uncertainty/value $\times 100$ = $1.0/50.0 \times 100$ = 2.0%.
- For a quotient of two independently measured quantities with maximum percentage uncertainties 2% and 3%, the summed maximum estimate is 5%.

Your turn: A 40 cm reading has an absolute uncertainty of 1 cm. Find percentage uncertainty.

Check the conclusion and its limits

- Repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error.
- Do not quote more decimal places than your measurement can support.

Not true: Repeating a measurement always removes a calibration offset. Repeating and averaging reduces RANDOM scatter in the mean. A calibration offset shifts every reading identically, so repeats land on the same wrong value; only recalibration removes it.

Key:

- Random variation makes repeated readings differ.
- For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation.
- Watch for: repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error.

Write from a percentage uncertainty of 5 percent

- A reading is 80 cm and the absolute uncertainty is 4 cm.
- Find the percentage uncertainty. Repeating a measurement does not remove a calibration offset.